

Practitioner's Docket No. TRW 2 256

CHAPTER II

Preliminary Classification:

Proposed Class:

Subclass:

NOTE: "All applicants are requested to include a preliminary classification on newly filed patent applications. The preliminary classification, preferably class and subclass designations, should be identified in the upper right-hand corner of the letter of transmittal accompanying the application papers, for example 'Proposed Class 2, subclass 129.'" M.P.E.P., § 601, 7th ed.

TRANSMITTAL LETTER
TO THE UNITED STATES ELECTED OFFICE (EO/US)

(ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)

PCT/DE98/02765	17/09/1998	17/09/1997
INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED

TITLE OF INVENTION

STATOR AND STATOR WINDING METHOD FOR USE WITH BRUSHLESS DIRECT CURRENT MOTORS

APPLICANT(S)

MULLER, Jurgén; PETER, Cornelius; WILKENDORF, Hardy

Box PCT

Assistant Commissioner for Patents

Washington D.C. 20231

ATTENTION: EO/US

CERTIFICATION UNDER 37 C.F.R. § 1.10*

(Express Mail label number is mandatory.)

(Express Mail certification is optional.)

I hereby certify that this Transmittal Letter and the papers indicated as being transmitted therewith is being deposited with the United States Postal Service on this date March 17, 2000, in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EL530412689US, addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231.

MICHAEL E. HUBZINSKI

(type or print name of person mailing paper)

Michael E. Hubzinski

Signature of person mailing paper

WARNING: Certificate of mailing (first class) or facsimile transmission procedures of 37 C.F.R. § 1.8 cannot be used to obtain a date of mailing or transmission for this correspondence.

***WARNING:** Each paper or fee filed by "Express Mail" must have the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 C.F.R. § 1.10(b).

"Since the filing of correspondence under § 1.10 without the Express Mail mailing label thereon is an oversight that can be avoided by the exercise of reasonable care, requests for waiver of this requirement will not be granted on petition." Notice of Oct. 24, 1996, 60 Fed. Reg. 56,439, at 56,442.

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 1 of 8)

NOTE: To avoid abandonment of the application, the applicant shall furnish to the USPTO, not later than 20 months from the priority date: (1) a copy of the international application, unless it has been previously communicated by the International Bureau or unless it was originally filed in the USPTO; and (2) the basic national fee (see 37 C.F.R. § 1.492(a)). The 30-month time limit may not be extended. 37 C.F.R. § 1.495.

WARNING: Where the items are those which can be submitted to complete the entry of the international application into the national phase are subsequent to 30 months from the priority date the application is still considered to be in the international state and if mailing procedures are utilized to obtain a date the express mail procedure of 37 C.F.R. § 1.10 must be used (since international application papers are not covered by an ordinary certificate of mailing—See 37 C.F.R. § 1.8).

NOTE: Documents and fees must be clearly identified as a submission to enter the national state under 35 U.S.C. § 371 otherwise the submission will be considered as being made under 35 U.S.C. § 111. 37 C.F.R. § 1.494(f).

- I. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. § 371:
- a. ☒ This express request to immediately begin national examination procedures (35 U.S.C. § 371(f)).
 - b. ☒ The U.S. National Fee (35 U.S.C. § 371(c)(1)) and other fees (37 C.F.R. § 1.492) as indicated below:

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 2 of 8)

2. Fees

CLAIMS FEE	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
<input type="checkbox"/>	TOTAL CLAIMS	11 - 20 =	0	× \$18.00 =	\$
	INDEPENDENT CLAIMS	3 - 3 =	0	× \$78.00 =	
	MULTIPLE DEPENDENT CLAIM(S) (if applicable) + \$260.00				
BASIC FEE**	<input type="checkbox"/> U.S. PTO WAS INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where an international preliminary examination fee as set forth in § 1.482 has been paid on the international application to the U.S. PTO: <input type="checkbox"/> and the international preliminary examination report states that the criteria of novelty, inventive step (non-obviousness) and industrial activity, as defined in PCT Article 33(1) to (4) have been satisfied for all the claims presented in the application entering the national stage (37 C.F.R. § 1.492(a)(4)) \$96.00 <input type="checkbox"/> and the above requirements are not met (37 C.F.R. § 1.492(a)(1)) \$670.00 <input checked="" type="checkbox"/> U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where no international preliminary examination fee as set forth in § 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in § 1.445(a)(2) to the U.S. PTO: <input type="checkbox"/> has been paid (37 C.F.R. § 1.492(a)(2)) \$760.00 <input type="checkbox"/> has not been paid (37 C.F.R. § 1.492(a)(3)) \$970.00 <input checked="" type="checkbox"/> where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 C.F.R. § 1.492(a)(5)) \$840.00				840.00
	Total of above Calculations				=840.00
SMALL ENTITY	Reduction by 1/2 for filing by small entity, if applicable. Affidavit must be filed also. (note 37 C.F.R. § 1.9, 1.27, 1.28)				-
	Subtotal				840.00
	Total National Fee \$				
	Fee for recording the enclosed assignment document \$40.00 (37 C.F.R. § 1.21(h)). (See item 13 below). See attached "ASSIGNMENT COVER SHEET".				
TOTAL	Total Fees enclosed				\$ 840.00

*See attached Preliminary Amendment Reducing the Number of Claims.

- i. ☒ A check in the amount of \$840.00 to cover the above fees is enclosed.
- ii. ☐ Please charge Account No. _____ in the amount of \$ _____.
A duplicate copy of this sheet is enclosed.

****WARNING:** "To avoid abandonment of the application the applicant shall furnish to the United States Patent and Trademark Office not later than the expiration of 30 months from the priority date: * * * (2) the basic national fee (see § 1.492(a)). The 30-month time limit may not be extended." 37 C.F.R. § 1.495(b).

WARNING: If the translation of the International application and/or the oath or declaration have not been submitted by the applicant within thirty (30) months from the priority date, such requirements may be met within a time period set by the Office, 37 C.F.R. § 1.495(b)(2). The payment of the surcharge set forth in § 1.492(e) is required as a condition for accepting the oath or declaration later than thirty (30) months after the priority date. The payment of the processing fee set forth in § 1.492(f) is required for acceptance of an English translation later than thirty (30) months after the priority date. Failure to comply with these requirements will result in abandonment of the application. The provisions of § 1.136 apply to the period which is set. Notice of Jan. 3, 1993, 1147 O.G. 29 to 40.

3. ☒ A copy of the International application as filed (35 U.S.C. § 371(c)(2)):

NOTE: Section 1.495 (b) was amended to require that the basic national fee and a copy of the International application must be filed with the Office by 30 months from the priority date to avoid abandonment. "The International Bureau normally provides the copy of the International application to the Office in accordance with PCT Article 20. At the same time, the International Bureau notifies applicant of the communication to the Office. In accordance with PCT Rule 47.1, that notice shall be accepted by all designated offices as conclusive evidence that the communication has duly taken place. Thus, if the applicant desires to enter the national stage, the applicant normally need only check to be sure the notice from the International Bureau has been received and then pay the basic national fee by 30 months from the priority date." Notice of Jan. 7, 1993, 1147 O.G. 29 to 40, at 35-36. See item 14c below.

- a. ☒ Is transmitted herewith.
- b. ☐ Is not required, as the application was filed with the United States Receiving Office.
- c. ☒ has been transmitted
 - i. ☒ by the International Bureau.
Date of mailing of the application (from form PCT/1B/308): date unknown
 - ii. ☐ by applicant on _____ (Date).

4. ☒ A translation of the International application into the English language (35 U.S.C. § 371(c)(2)):

- a. ☒ Is transmitted herewith.
- b. ☐ Is not required as the application was filed in English.
- c. ☐ was previously transmitted by applicant on _____ (Date).
- d. ☐ will follow.

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 4 of 8)

5. ☒ Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. § 371(c)(3)):

NOTE: The Notice of January 7, 1993 points out that 37 C.F.R. § 1.495(a) was amended to clarify the existing and continuing practice that PCT Article 19 amendments must be submitted by 30 months from the priority date and this deadline may not be extended. The Notice further advises that: "The failure to do so will not result in loss of the subject matter of the PCT Article 19 amendments. Applicant may submit that subject matter in a preliminary amendment filed under section 1.121. In many cases, filing an amendment under section 1.121 is preferable since grammatical or idiomatic errors may be corrected." 1147 O.G. 29-40, at 36.

- a. ☐ are transmitted herewith.
 - b. ☐ have been transmitted
 - i. ☐ by the International Bureau.
Date of mailing of the amendment (from form PCT/1B/308): _____
 - ii. ☐ by applicant on _____ (Date).
 - c. ☐ have not been transmitted as
 - i. ☐ applicant chose not to make amendments under PCT Article 19.
Date of mailing of Search Report (from form PCT/ISA/210): _____
 - ii. ☐ the time limit for the submission of amendments has not yet expired.
The amendments or a statement that amendments have not been made will be transmitted before the expiration of the time limit under PCT Rule 46.1.
6. ☒ A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. § 371(c)(3)):
- a. ☒ is transmitted herewith.
 - b. ☐ is not required as the amendments were made in the English language.
 - c. ☐ has not been transmitted for reasons indicated at point 5(c) above.
7. ☒ A copy of the international examination report (PCT/IPEA/409)
- ☒ is transmitted herewith.
 - ☐ is not required as the application was filed with the United States Receiving Office.
8. ☐ Annex(es) to the international preliminary examination report
- a. ☐ is/are transmitted herewith.
 - b. ☐ is/are not required as the application was filed with the United States Receiving Office.
9. ☐ A translation of the annexes to the international preliminary examination report
- a. ☐ is transmitted herewith.
 - b. ☐ is not required as the annexes are in the English language.

10. ☒ An oath or declaration of the inventor (35 U.S.C. § 371(c)(4)) complying with 35 U.S.C. § 115
- a. ☐ was previously submitted by applicant on _____ (Date).
 - b. ☐ Is submitted herewith, and such oath or declaration
 - i. ☐ Is attached to the application.
 - ii. ☐ Identifies the application and any amendments under PCT Article 19 that were transmitted as stated in points 3(b) or 3(c) and 5(b); and states that they were reviewed by the inventor as required by 37 C.F.R. § 1.70.
 - c. ☒ will follow.

II. Other document(s) or information included:

11. ☒ An International Search Report (PCT/ISA/210) or Declaration under PCT Article 17(2)(a):
- a. ☒ Is transmitted herewith.
 - b. ☐ has been transmitted by the International Bureau.
Date of mailing (from form PCT/IB/308): _____
 - c. ☐ is not required, as the application was searched by the United States International Searching Authority.
 - d. ☐ will be transmitted promptly upon request.
 - e. ☐ has been submitted by applicant on _____ (Date).
12. ☒ An Information Disclosure Statement under 37 C.F.R. §§ 1.97 and 1.98:
- a. ☐ Is transmitted herewith.
Also transmitted herewith is/are:
 - ☐ Form PTO-1449 (PTO/SB/08A and 08B).
 - ☐ Copies of citations listed.
 - b. ☒ will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. § 371(c).
 - c. ☐ was previously submitted by applicant on _____ (Date).
13. ☒ An assignment document is transmitted herewith for recording. (in blank)
A separate ☐ "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or ☐ FORM PTO 1595 is also attached.

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 6 of 8)

14. ☒ Additional documents:

- a. ☒ Copy of request (PCT/RO/101)
- b. ☒ International Publication No. WO 99/14840
- i. ☐ Specification, claims and drawing
- ii. ☒ Front page only
- c. ☐ Preliminary amendment (37 C.F.R. § 1.121)
- d. ☐ Other
 -Voluntary Submission of Substitute Specification Under
 37 C.F.R. 1.125; - Translation of International
 Examination Report (PCT/IDEA/409)

15. ☒ The above checked items are being transmitted

- a. ☒ before 30 months from any claimed priority date.
- b. ☐ after 30 months.

16. ☐ Certain requirements under 35 U.S.C. § 371 were previously submitted by the applicant on _____, namely:

AUTHORIZATION TO CHARGE ADDITIONAL FEES

WARNING: Accurately count claims, especially multiple dependant claims, to avoid unexpected high charges if extra claims are authorized.

NOTE: "A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).

NOTE: "Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).

☒ The Commissioner is hereby authorized to charge the following additional fees that may be required by this paper and during the entire pendency of this application to Account No. 06-0308

☒ 37 C.F.R. § 1.492(a)(1), (2), (3), and (4) (filing fees)

WARNING: Because failure to pay the national fee within 30 months without extension (37 C.F.R. § 1.495(b)(2)) results in abandonment of the application, it would be best to always check the above box.

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 7 of 8)

☒ 37 C.F.R. § 1.492(b), (c) and (d) (presentation of extra claims)

NOTE: Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.492(d)), it might be best not to authorize the PTO to charge additional claim fees, except possible when dealing with amendments after final action.

☒ 37 C.F.R. § 1.17 (application processing fees)

☒ 37 C.F.R. § 1.17(a)(1)-(5) (extension fees pursuant to § 1.136(a).

☐ 37 C.F.R. § 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. § 1.311(b))

NOTE: Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 C.F.R. § 1.311(b).

NOTE: 37 C.F.R. § 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying . . . issue fee." From the wording of 37 C.F.R. § 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

☒ 37 C.F.R. § 1.492(e) and (f) (surcharge fees for filing the declaration and/or filing an English translation of an International Application later than 30 months after the priority date).

Reg. No.: 26,482 / 34,185

Tel. No.: (216) 861-5582

Customer No.:

SIGNATURE OF PRACTITIONER

James W. McKee / Michael E. Hudzinski
(type or print name of practitioner)

1100 Superior Avenue, Seventh Floor
P.O. Address

Cleveland, OH 44114

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 8 of 8)

09/508934

430 Rec'd PCT/PTO 17 MAR 2000

EXPRESS MAIL CERTIFICATE

"Express Mail" EL530412689US
Date of Deposit: March 17, 2000

I hereby certify that this **PRELIMINARY AMENDMENT** is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to: Assistant Commissioner For Patents, Washington, D.C. 20231

By Michael S. Indyk

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:) Examiner: Unknown
MÜLLER, et al.)
Serial No.: Unknown) Art Unit: Unknown
Filed: Herewith)
For: STATOR AND STATOR)
WINDING METHOD FOR USE)
WITH BRUSHLESS DIRECT)
CURRENT MOTORS)
Date of Last Office Action:)
None)
Attorney Docket No.:)
TRW 2 0256)
Cleveland, Ohio 44114-2518
March 17, 2000

PRELIMINARY AMENDMENT
UNDER 37 C.F.R. §1.121

Assistant Commissioner of Patents
Washington, D.C. 20231

Dear Sir:

Prior to substantive examination of the above-referenced patent application, applicants respectfully request amendment of the application as follows:

IN THE CLAIMS:

Please cancel claims 2-4 and 6-10 from further consideration herein.

Please amend claims 1 and 5 as follows:

1. (Amended) [Method] A method for winding a stator [for] of a brushless direct current motor, [a] which has a stator body (9) with a pre-determined number of to be wound stator teeth (3), [b)] wherein the stator
5 teeth (3) are respectively wound with two coils (W1, W3; W2, W4), which are magnetically coupled and which permit the generation of opposite magnetic fields by the supply of current with variable directional orientation, and [c)] wherein each of the two coils (W1, W3; W2, W4) comprises
10 a predetermined number of conductors placed in parallel, [characterized in that d) the stator teeth (3) are each] the method comprising the steps of:
simultaneously [wound,] each of the stator teeth (3) in several partial winding steps, with [two conductors (25, 27) or] an even number of 2n conductors[, e) that one of the two conductors (25, 27) or]
15 allocating a first set of n [conductor] conductors of the 2n conductors [of the one] to a first coil and [the other of the two conductors (25, 27) or] allocating the other set of n [conductor] conductors of the 2n conductors [are allocated] to the other coil; and,
20 [f) that] performing a predetermined number of partial winding procedures [is performed] until the predetermined number of conductors per coil (W1, W3; W2, W4) has been reached.
25

5. (Amended) Stator for a brushless direct current motor, [a)which presents] the stator comprising:

a stator body (9) with a pre-determined number of wound stator teeth (3), [b) wherein] the stator teeth (3) [are] being respectively wound with two coils (W1, W3; W2, W4) which are magnetically coupled and which facilitate by the supply of current of variable directional orientation the generation of [opposite] opposing magnetic fields[, and c)wherein] in said stator teeth;

each of the two coils (W1, W3, or W2, W4) [comprises] including a predetermined even number of [in parallel arranged] 2n conductors, [characterized in that d) two each conductors (25, 27) of which one conductor is allocated to the one coil and the other conductor to the other coil, or 2n conductors,] of which a first set of n [conductor is] conductors are allocated to a first one of the [one coil] two coils and the other n conductors are allocated to the other coil[, are] of the two coils; and,

the 2n conductors being conducted over the stator teeth in a substantially constant position [vis-a-vis] relative to each other over the entire coil length.

Please add new claims 11-19 as follows:

11. A coil winding method for winding a predetermined number of conductors (25, 27) to form a set of magnetically coupled coil pairs (W1, W3,; W2, W4;...) on a plurality of stator teeth (3) of a stator body (9) in
5 a brushless direct current motor, each set of coil pairs (W1, W3, W2, W4;...) generating opposing magnetic fields in the plurality of stator teeth (3), the coil winding method comprising the steps of:

a) in a first partial coil winding step,
10 simultaneously winding $2n$ conductors (25, 27) together onto a first plurality of stator teeth of said stator body;

b) selecting a first group n_1 (25) of said $2n$ conductors and assigning the first group n_1 (25) to a first
15 coil (W1) of said set of magnetically coupled coil pairs;

c) selecting a second group n_2 (27) of said $2n$ conductors and assigning the second group n_2 (27) to a second coil (W3) of said set of magnetically coupled coil pairs; and,

20 d) repeating steps a) through c) until said predetermined number of conductors are wound onto said first plurality of stator teeth to form a first magnetically coupled coil pair (W1, W3) of said set of magnetically coupled coil pairs (W1, W3; W2, W4;...).

12. The method according to claim 11 further including:

winding said predetermined number of conductors on a second plurality of stator teeth of said stator body
5 (9) in said brushless direct current motor to form a second magnetically coupled coil pair (W2, W4) of said set of magnetically coupled coil pairs (W1, W3; W2, W4;...).

13. The method according to claim 12 wherein the step of winding said predetermined number of conductors on said second plurality of stator teeth includes the steps of:

5 e) in a second partial coil winding step, simultaneously winding $2n$ conductors together onto a second plurality of stator teeth of said stator body;

f) selecting a third group n_3 of said $2n$ conductors and assigning the third group n_3 to a third coil
10 (W2) of said set of magnetically coupled coil pairs;

g) selecting a fourth group n_4 of said $2n$ conductors and assigning the fourth group n_4 to a fourth coil (W4) of said set of magnetically coupled coil pairs; and,

15 h) repeating steps e) through g) until said predetermined number of conductors are wound onto said second plurality of stator teeth to form said second magnetically coupled coil pair (W2, W4) of said set of magnetically coupled coil pairs (W1, W3; W2, W4;...).

14. The method according to claim 13 wherein;
the first partial coil winding step includes simultaneously winding said $2n$ conductors onto said first plurality of stator teeth different from said second
5 plurality of stator teeth; and,

the second partial coil winding step includes simultaneously winding said $2n$ conductors onto said second plurality of stator teeth different from said first plurality of stator teeth.

15. The method according to claim 14 wherein:
the first partial coil winding step of simultaneously winding said $2n$ conductors onto said first

plurality of stator teeth includes simultaneously winding
5 two conductors onto said first set of six stator teeth;
and,

the second partial coil winding step of
simultaneously winding said $2n$ conductors onto said second
plurality of stator teeth includes simultaneously winding
10 two conductors onto said second set of six stator teeth.

16. The method according to claim 11 wherein:
the step of assigning said first group n_1 of said
 $2n$ conductors includes, prior to performing each said at
least one first partial winding step, connecting said
5 first group n_1 of said $2n$ conductors to a first electrical
connection contact 15_I on said stator body; and,

the step of assigning said second group n_2 of
said $2n$ conductors includes, prior to performing each said
at least one first partial winding step, connecting said
10 second group n_2 of said $2n$ conductors to a second
electrical connection contact 15_{II} on said stator body.

17. The method according to claim 16 wherein:
the step of assigning said first group n_1 of said
 $2n$ conductors further includes, after performing said each
at least one first partial winding step, connecting said
5 first group n_1 of said $2n$ conductors to a third electrical
connection contact 15_{III} on said stator body; and,

the step of assigning said second group n_1 of
said $2n$ conductors further includes, after performing said
each at least one first partial winding step, connecting
10 said second group n_2 of said $2n$ conductors to a fourth
electrical connection contact 15_{IV} on said stator body.

18. A stator made using the steps according to
claim 11.

19. A stator made using the steps according to claim 13.

Remarks


Applicants respectfully request that the foregoing amendments be entered prior to substantive examination of the application. These changes are submitted to place the application in better form for examination.

Related Application

Applicants note for the convenience of the Examiner that an application was filed on March 17, 2000 entitled "STATOR WITH INJECTION MOLDED INSULATION LAYER AND INTEGRAL SUPPORT ELEMENT CARRYING ELECTRICAL CONNECTION CONTACTS FOR USE WITH BRUSHLESS DIRECT CURRENT MOTORS" containing some subject matter overlap with the instant application.

Respectfully submitted,

FAY, SHARPE, FAGAN,
MINNICH & MCKEE, LLP



James W. McKee
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09/508934

430 Rec'd PCT/PTO 17 MAR 2000

EXPRESS MAIL CERTIFICATE

"Express Mail" EL530412689US
Date of Deposit: March 17, 2000

I hereby certify that this **VOLUNTARY SUBMISSION OF SUBSTITUTE SPECIFICATION** is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to: Assistant Commissioner For Patents, Washington, D.C. 20231

By

Michael E. Dwyer

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:)	Examiner: Unknown
MÜLLER, et al.)	
)	Art Unit: Unknown
Serial No.: Unknown)	
)	
Filed: Herewith)	
)	
For: STATOR AND STATOR)	
WINDING METHOD FOR USE)	
WITH BRUSHLESS DIRECT)	
CURRENT MOTORS)	
)	
Date of Last Office Action:)	
None)	
)	
Attorney Docket No.:)	
TRW 2 0256)	
)	

Cleveland, Ohio 44114-2518
March 17, 2000

VOLUNTARY SUBMISSION OF
SUBSTITUTE SPECIFICATION
UNDER 37 C.F.R. §1.125

Assistant Commissioner For Patents
Washington, D.C. 20231

Dear Sir:

Applicants respectfully request that the attached specification be used as a substitute for the original specification as filed. It is respectfully submitted that the original specification is a direct literal translation of the German priority document and, accordingly, is not in proper idiomatic English. The attached substitute specification is in proper idiomatic

English and is in compliance with 37 C.F.R. §1.52(a) and (b).

Applicants respectfully submit that the number and nature of the amendments to the original specification would render it difficult to consider the application and to arrange the papers for printing and copying. Accordingly, the attached substitute specification is submitted. By entering the enclosed substitute specification, the Office will receive the advantage of saving the time needed to enter the amendments into the specification and, further, realize a reduction in the number of printing errors that may arise.

Applicants respectfully submit that the attached substitute specification includes no new matter.

Respectfully submitted,

FAY, SHARPE, FAGAN,
MINNICH & McKEE, LLP

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STATOR AND STATOR WINDING METHOD FOR USE WITH BRUSHLESS
DIRECT CURRENT MOTORSBackground of the Invention

5 The subject invention is directed toward the art
of electric motor stator devices and, more particularly,
to a stator apparatus and winding method for use in
winding coils in brushless direct current motors. The
method uses a series of partial coil windings steps
including winding an even number of conductors together
onto a set of stator teeth, allocating half of the
conductors to a first coil wound onto the stator teeth and
10 allocating the second half of the conductors to a second
coil wound onto the stator teeth. The above partial coil
winding step is successively repeated until a
predetermined number of conductors are wound onto a first
set of stator teeth. The apparatus includes the device
15 produced by the method.

The invention is especially well suited for use
in manufacturing electric motor stators for automotive
applications where there is a need for easily activatable
and inexpensive motors. Examples of typical such
20 applications include electrically activatable hydraulic
pumps in power assisted control systems. Although the
present invention finds use in a wide variety of
applications, with regard to hydraulic pump use, brushless
direct-current motors, specifically four-phase direct
25 current motors, are primarily suitable because of their
high degree of efficiency and ease of maintenance.
Accordingly, the present invention will be described in
detail in connection with the four-phase direct current
motor embodiment.

In accordance with known techniques, in order to enable extremely simple motor control, the coils forming separate phases of the motor are respectively frequently selected through use of an actuatable electronic switch device such as, for example, a power semiconductor. The coils are thereby intermittently connected, in a known fashion, with a source of direct current. When one phase in the respective coil is switched off, a negative tension peak is created as a result of the coil self-induction. Typically, the negative tension peak relative to the normal direction of current is discharged via diodes that are polled in an inverse direction and, typically, are positioned in parallel to their respective electronic switch element. This results, however, in a corresponding current in the opposite direction which must be taken into consideration in the selection of the conductors forming the coil windings. The current intensity caused by self-induction can have a negative effect upon the efficiency of the motor.

In order to solve the above problem, WO-A-96/22629 suggests to magnetically couple coil pairs in a four-phase direct current motor. As taught there, two coils are applied on each pole and/or each group of poles which are charged with a direct current in opposite directions in order to generate the desired opposite polarity of the magnetic fields generated by the coils. The orientation of the two coils need not be established by winding them in opposite directions on the stator, providing that the ends of the two coils are oppositely connected with respect to the source of direct current.

As a result of the magnetic coupling of the two coils produced by means of the above technique, the tension induced in the respective coil from self-induction during discharge of the respective phase is compensated

for by a tension induced in the coupled coil. The stored magnetic energy is discharged via the diode which is arranged in parallel to the electronic switch selecting the coupled coil. This produces an improvement in the degree of motor efficiency.

As a further improvement, it is known from WO-A-96/22629 that better results are obtainable when the coils are wound simultaneously. This results in a closer proximity of the wires of the two coupled coils and thus improves coupling inductivity.

Since, however, due to the high currents experienced in brushless direct current motors, several parallel conducting wires are needed for each coil so as to better distribute the current load. Therefore, it becomes necessary in the prior art to allocate the loose wire ends of the two coils following the winding process during which all parallel wires of both coils are wound at the same time. To that end, in the prior art, it was necessary to at least mark the lead and trailing free ends of the coil wires or to subsequently undertake wire coil assignments by means of current passage measurements, or the like. All together, automation of the winding process and allocation of the free wire ends to the coils forming the motor and/or to the contacting of the coils electrically in an automated way was not possible.

Accordingly, it is desirable to provide a method for winding a stator of a brushless direct-current motor whereby, as a result of simplification of the manufacturing method, automation of the winding process is made possible and, in addition, automation of the allocation of the free wire ends leading to the coils is also made possible.

It is further desirable to provide a motor stator that is constructed in accordance with the above method.

5

Summary of the Invention

10 The subject invention provides a stator winding method and a stator produced thereby which are simple, efficient, and easily automated. The stator winding method winds a predetermined number of conductors to form a set of magnetically coupled coil pairs on a plurality of stator teeth of a stator body in a brushless direct current motor, each set of coil pairs generating opposing magnetic fields in the plurality of stator teeth. The coil winding method includes at least one or a series of partial coil winding steps. In each partial coil winding step, $2n$ conductors are simultaneously wound together onto a first plurality of stator teeth of the stator body. A first group of a first half of the $2n$ conductors are assigned to a first coil of the set of magnetically coupled coils. A second group (the other half) of the $2n$ conductors are assigned to a second coil of the set of magnetically coupled coil pairs. The above partial coil winding steps are repeated until the predetermined number of conductors are wound onto the first plurality of stator teeth.

25

30 The invention advantageously uses the results that are achieved by dividing the winding procedure for each pair of coupled coils (of the opposite phases) into a series of one or more partial winding steps. Significant simplification is attained in the manufacturing method and thus is easily extendable for automation. In each partial winding procedure, $2n$ are wound. In the preferred embodiment, two wires are wound. Thereafter, a first half of the $2n$ conductors are

allocated to the first coil and the other half to the $2n$ conductors are allocated to the other coil. In the preferred embodiment, a first wire is allocated to the first coil and the other wire is allocated to the second coil.

In comparison with stators produced according to the known methods, stators produced according to the present invention have a further improved magnetic coupling between the coils of the respectively opposite phases. It is believed that the simultaneous winding of all the wires of the two coils and the allocation of the wire ends after the winding procedure produces a more or less random allocation and positioning of the individual wires within each single coil. By separation of the winding into partial winding steps, closer proximity of the individual wires of the coils or intermingling therebetween is achieved, at least on balance, to arrive at a more uniform winding distribution as viewed in cross section through the coil. In particular, the above is especially true when winding only two wires respectively, one wire per coil, because the two wires are placed close to each other over the entire coil length.

In addition to the above, an improved capacity of replicating the electrical properties of each stator produced in accordance with the present invention is enhanced. More particularly, through use of the present invention, the electrical properties of the stators produced thereby are very repeatable.

In accordance with another aspect of the present invention, prior to each partial winding procedure, the lead terminal ends of the first half of the $2n$ conductors are allocated to a first connection contact. Similarly, prior to each partial winding procedure, the other half of the $2n$ conductors are allocated to a second connection

contact. In the preferred embodiment described below, the first conductor is allocated to the first connection contact and the other conductor is allocated to the second connection contact.

5 After each partial winding operation, the trailing or other free end of the first half of the $2n$ conductors are allocated to a third connection contact and the trailing free ends of the other half of the $2n$ conductors are allocated to a fourth connection contact.
10 In that way, the first and third connection contacts serve for electrical connections to the first coil and the second and fourth connection contacts serve for electrically connecting to the other coil.

15 Allocation of the free ends of the wire leads prior to each partial winding procedure is preferably accomplished by means of soldering, welding, clamping, or the like. As a result of such fixing of the free ends of the coil wires, no additional holding or fixturing of these free ends is needed when the method of the invention
20 is executed in an automatic winding device. After each partial winding procedure, the free trailing ends of the wires are likewise connected with the appropriate connection contacts.

25 It is an advantage of the present invention that through use of the simultaneous winding of only two wires in accordance with the preferred embodiment, it is possible to maintain, in a simple fashion, the allocation of the wires during the entire winding procedure. Therefore, no additional measures are needed for the
30 allocation, such as marking of the wires or passage of a measuring current therethrough to determine the coil-conductor correspondence.

 In the preferred apparatus embodiment of the invention, a stator is provided having connection contacts

preferably on a front side thereof. The connection contacts include a number of fastening means which correspond to the number of required partial winding procedures or operations. This guarantees that before and after each partial winding procedure, it is possible to readily connect the free wire ends (lead and trailing) with the appropriate connection contact(s). Thereby, for each wire end or for each group of n wires of the $2n$ simultaneously wound wires, an individual attachment means or a clamp is provided.

Brief Description of the Drawings

The invention may take physical form in certain parts and arrangements of parts, a preferred embodiment of which will be described in detail in this specification and illustrated in the accompanying drawings which form a part hereof, and wherein:

FIGURE 1 is a schematic representation of a four-phase direct current motor with an associated motor control circuit;

FIGURE 2 is a perspective view of a stator formed in accordance with the present invention;

FIGURE 3 is a schematic representation of segments of the stator of Figure 1 unwound in lateral view illustrating the preferred winding method in accordance with an embodiment of the invention; and,

FIGURE 4 is a perspective view of the stator represented in Figure 1 showing the motor control circuit mounted thereon in accordance with the present invention.

Detailed Description of the Preferred Embodiment

Referring now to the drawings wherein the showings are for the purposes of illustrating the preferred embodiment of the invention only and not for

purposes of limiting same, Figure 1 depicts a schematic representation of a four-phase direct current motor including a stator 1 upon which are provided a plurality of stator coils W1, W2, W3, W4. The coils W1-W4 are wound on teeth or poles 3 (Fig. 2) of the stator 1. The indicated magnetic coil couplings are illustrated using the standard "dot" convention. The opposing magnetic phases I and III on corresponding coils W1 and W3, as well as opposing magnetic phases II and IV on corresponding coils W2 and W4 are realized by winding coils W1 together with coils W3 on the same (shared) set of stator teeth and, similarly, by winding the coils W2 and coils W4 on the same (shared) stator teeth.

It is to be appreciated that opposite magnetic fields are produced in the regions of the stator poles 3 facing the motor rotor (not shown) by winding or connecting the coils W1 and W3 or W2 and W4 appropriately and in a manner to be described in detail below. The opposite magnetic fields that are produced in accordance with the invention by winding or contacting the coils W1 and W2 or W2 and W4 is indicated in Figure 1 by the dot convention at the coils W1-W4.

Each coil W1-W4 is connected on one end or one connection to a direct current source 5. The other end or other connection of each coil is connected with a selectively activated electronic switch S1, S2, S3, S4, preferably a power semiconductor such as, for example, a field effect transistor (FET). As illustrated, each switch S1-S4 is connected, at its control terminal with the motor control unit 7. The motor control unit 7 connects the coils W1-W4 for specified time intervals in a known fashion with the direct current source 5 by appropriate activation of switches S1-S4.

With continued reference to Figure 1, a set of diodes D1, D2, D3, D4 are connected in parallel with each of the selectively actuatable switches S1-S4. The diode orientation is preferably selected as shown so that current is conducted in a single direction in such a manner that the blocking of the associated diode occurs with each opening of the respective switch S1-S4.

As a result of coupling the respectively opposite phases I and II or II and IV and diodes D3 and D1 or D4 and D2, the discharge of the stored magnetic energy is achieved when the appropriate phase is switched off. This provides an improvement in the degree of efficiency of the motor.

Turning now to Figure 2, the overall construction of the preferred embodiment of the subject stator 1 is shown in perspective view. As illustrated, the stator includes twelve (12) stator poles 3. The stator body 9 includes, in customary fashion, a base body portion 10 formed of packeted stator sheet metal pieces which are stacked to extend vertically relative to the longitudinal axis of the stator. The packet of stator sheet metal pieces are preferably formed initially in accordance with well known techniques such as the usual manner of stamp-press packeting, whereby, respectively, two or more stacked sheet metal pieces are joined together by application of spot pressure.

In accordance with the present invention, the packet of stacked and joined stator sheet metal pieces is subsequently injection-coated with plastic in an injection molding operation, whereby a plastic layer is produced preferably at least within the interior regions of the stator teeth that are expected to come into contact with the conductors forming the windings of the coils W1-W4.

Because of the technique in accordance with the present invention of injection-coating interior regions of the stator teeth that are to come in contact with conductors of the coils forming the motor, it becomes no longer
5 necessary to effect a powder coating of these regions in order to prevent damage to the insulation layer of the coil wires, particularly during the winding process.

Still further in accordance with the invention, preferably simultaneously with the formation of the plastic coating insulation layer on the stator body in the
10 injection molding process, a plurality of winding aids 11 are injection-sprayed onto the frontal sides of the stator teeth in the same injection-molding operation. The winding aids 11 are disposed along the stator and are
15 preferably shaped as shown for providing location guidance control for the coil wires during winding of the coils W1-W4. Further, the plurality of winding aids 11 simultaneously fix the position of the portions of the coils that protrude beyond the frontal sides of the stator
20 teeth 3.

The upper side of the stator body 9 is provided with a sprayed-on support ring 13 having an outwardly extending shoulder portion 13a. The support ring is formed during the injection molding operation. After the
25 support ring 13 is formed onto the stator, a plurality of electrical connection contacts 15 are selectively pressed in suitably arranged recesses formed in the circular wall defined by the shoulder 13a. To that end, the ring 13 is molded with a plurality of recesses for receiving terminal
30 ends of the electrical connection contacts. Preferably, the connection contacts 15 are manufactured separately by pressing and bending sheet metal components into the preferred form illustrated.

A longitudinally extending wall 17 is formed by the support ring 13, the wall 17 extending above the shoulder 13a of the ring. The wall 17 is advantageously used for fixing and mounting of an electric motor control circuit board 18 as best shown in Figure 4. The control circuit may have, for said purpose, a spray-coated plastic stamped grid 19 with appropriate recesses 21 for mating with the wall 17 of the support ring 13. The underside of the stamped grid 19 rests in abutting relationship on the shoulder 13a of the support ring 13.

As further shown in Figure 4, the top regions or upper tab portions of the plurality of electrical connection contacts 15 connect with perforations 23 formed in conductor pathways 19a of the stamped grid 19. The upper tab portions of the electrical connection contacts 15 preferably extend through the motor control circuit board 18 and can be joined with the conductor pathways 19a through simple mechanical connection, by means of soldering, welding, or the like.

By injection-coating the packet of stacked stator sheet metal pieces with a plastic coating insulation layer in a single injection molding work step, whereby the interior regions of the stator teeth 3 are spray-coated and, concurrently, a ring 13 and winding aids 11 are integrally formed and molded onto the stator, an extremely cost effective stator manufacturer is obtained. In addition, the arrangement of the plurality of connection contacts 15 directly at the stator 1 by press-fitting them into recesses provided in the support ring 13 formed in the injection molding operation, permits simple electrical and mechanical connection between the lead ends of the stator coils and conductive portions of the motor control circuit 18.

With reference next to Figure 4, the preferred method for winding the stator in accordance with the present invention will be explained. As a starting point, it is to be noted that in the represented specific embodiment of the present invention, each of the coils **W2-W4** extends over a totality of six (6) stator teeth **3**, which are divided in a known fashion into respectively opposite groups of three each adjacent stator teeth. As noted above, these six (6) stator teeth each support two coupled coils, i.e. the coils **W1** and **W3** or **W2** and **W4**. In Figure 3, two of these groups are represented, whereby, hereinafter, for the sake of simplicity, these coils are identified as **W1** and **W3**. The remaining six (6) stator teeth **3** of the coils **W2** and **W4** are wound in a similar fashion. In that regard, the method described below applies equally as well to the remaining stator teeth of the coils **W2** and **W4** and to more stator teeth and coil pairs for larger-sized stators.

Each of the coils **W1-W4** includes, due to the required high amperage capacity requirements, several partial windings of individual wires arranged in parallel. Multiple successive partial winding operations are performed until the coil is formed having the predetermined number of conductors. In accordance with the invention, in each case, **2** or **2n** wires (an even number of wires) are simultaneously wound on the appropriate stator teeth **3** during each partial coil winding operation. In the preferred embodiment illustrated, a single pair of two (2) wires **25, 27** are wound on the appropriate stator teeth during each partial coil winding operation.

In the two (2) wire embodiment, the lead ends of the wire pair **25, 27** are first respectively connected with a first electrical connection contact **15₁** and a second

electrical connection contact 15_{II}. For that purpose, the electrical connection contacts are preferably bent into the shape of a V-shaped clamping groove 15a into which the stripped wire lead ends of the coils are embedded and at least temporarily fixed into place by bending the walls of the clamping grooves 15a together or by forming a connection loop. Electrical contact can be established in a number of ways such as, for example, with a separate welding device whereby the insulation of the wires is preferably perforated or removed simultaneously with the contacting step.

After the lead ends of the wire pair 27, 27 are attached, the first stator tooth 3 of the first group of three teeth is wound up in a first partial winding operation. This is done, as shown, in a counter-clockwise direction in the specific embodiment depicted in Figure 3. After the desired number of windings have been applied, the next adjacent stator tooth is wound in the opposite direction with the desired number of windings. This is illustrated at the middle stator tooth 3 of the left group in Figure 3. Next, the last stator tooth of the first group of three is wound with the desired number of windings in a counter-clockwise direction as shown. This is illustrated at the right stator tooth 3 of the left group in Figure 3.

Thereafter, the first stator tooth of the diametrically opposite group of three (in Figure 3 the right stator tooth of the right group of three) is wound in a clockwise direction as shown. The winding of the second group of three stator teeth is executed in a fashion similar to the first group of three stators wherein the middle stator tooth is wound in a counter-clockwise direction and the left stator tooth is wound in a clockwise direction.

After winding the last stator tooth of the second group of three (left stator tooth of the right group of three in Figure 3) the end of wire 25 is connected with the third connection contact 15_{III} and the end of wire 27 with the fourth connection contact 15_{IV}. Allocation of the wire ends to the connection contacts 15 is initially unimportant for this first partial winding step. Of course, a record must be kept of which of the connection contacts 15 corresponds to these coils W1 and W3. In other words, it must be known for future actuation of coils which of the two coils corresponds to which of the two connection contacts. The coils W1 and W3 are equivalent, since they have the same winding directions.

Upon completion of this first partial winding step, second, third, fourth, etc. partial winding steps are performed in similar fashion. The only difference consists in that the wire ends are connected to additional fastening means or clamping grooves 15a of the first to fourth connection contacts 15_I-15_{IV}. This makes possible simple attachment of the wire ends without the necessity of first loosening the previously wound wires.

Attention must be paid, however, with respect to said second and eventually subsequent partial winding steps that the allocation selected in the first partial winding step for connection contact 15_I and 15_{III} to one coil, for example to coil W1, or the allocation of connection contacts 15_{II} and 15_{IV} to the other coil, for example coil W3, is adhered to.

It is customary, however, to establish from the very beginning of the series of partial winding operations that certain connection contacts correspond to certain coils or coil ends.

By allocation the wire ends to certain connection contacts prior to the actual winding and by maintaining the allocation during the partial winding step, it is possible, in simple fashion, to correctly connect, after the partial winding process, the wire ends to the correct connection contacts without the need for additional measures, such as the marking of wires or the performance of passage measurements. This is particularly true with respect to a small number of simultaneously wound wires (preferably two wires).

Furthermore, by fixing the conductor lead ends immediately prior to each partial winding step and the trailing ends immediately after each partial winding step, there is the benefit that loosening of the windings is avoided, particularly loosening of the last windings. Handling ability of the wound stators during motor installation is also improved, since it is not possible for the ends of the windings forming the conductors to detrimentally affect the installation.

All in all, as many partial winding steps are performed as is necessary for obtaining the required number of parallel wires for each coil **W1**, **W3**. The number of fastening means or clamping grooves **15a** at the connection contacts preferably corresponds, in such arrangement, to the number of the required partial winding steps.

The two coupled coils **W2** and **W4** are produced in similar fashion, and attention is to the paid that the direction of the windings are also correctly selected for the already established coils **W1** and **W3**.

The described method is, of course, not only applicable with respect to four-phase direct current motors, but can also be applied for motors with any random

(even) number of phases, whereby, in each case, the coils of two phases are magnetically coupled.

5 The invention has been described with reference to the preferred embodiment. Obviously, modifications and alterations will occur to others upon a reading and understanding of this specification. It is intended to include all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.


WELTORGANISATION FÜR GEISTIGES EIGENTUM
 Internationales Büro
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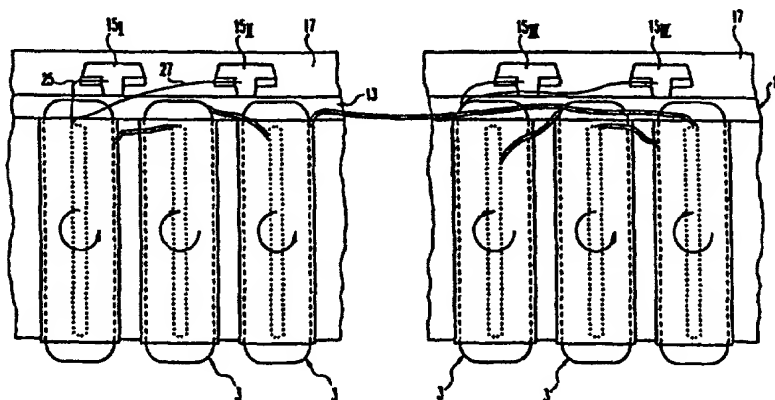
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(54) Title: STATOR AND STATOR WINDING METHOD FOR A BRUSHLESS DIRECT-CURRENT MOTOR

(54) Bezeichnung: STATOR UND VERFAHREN ZUM BEWICKELN EINES STATORS FÜR EINEN BÜRSTENLOSEN GLEICHSTROMMOTOR

(57) Abstract

Disclosed is a stator winding method for a brushless direct-current motor including a stator body (9) with a number of stator teeth (3), each of which is wound with two magnetic-coupling coils (W1, W3; W2, W4) enabling contrary magnetic fields to be created due to the fact that the current in said coils flow in two opposite directions and that each of the two coils (W1, W3; W2, W4) is comprised of a number of conductors connected in parallel. According to the invention, the stator teeth (3) are wound in various partial-winding operations with two conductors (25, 27) or an even number of 2n conductors, of which one (25, 27) or n conductor from the 2n conductors is assigned to one coil, while the other of the two conductors (25, 27) or the other n conductors of the 2n conductors is assigned to the other coil. A number of partial-winding operations are performed until the set number of conductor per coil (W1, W3; W2, W4) has been reached. The invention also relates to an appropriate stator.



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Translation

Stator and Stator-winding Method for a Brushless Direct Current Motor.

The invention relates to a stator-winding method for a brush-less direct current motor with the characteristics of the Preamble to Patent Claim 1, as well as an appropriate stator with the characteristics of the Preamble to Patent Claim 5.

Specifically in automotive engineering there is a need for employing cost-effective motor-driven driving mechanisms, which are rather simple to control and quite inexpensive to produce, for example for an electrically controllable hydraulic pump for power steering. With respect to the mentioned application case, primarily brushless direct-current motors, specifically four-phase direct-current motors, are suitable because of their high degree of efficiency and ease of maintenance.

In order to permit extremely simple motor control, the coils realizing one phase respectively are frequently selected via one actuatable electronic switch, for example a power semiconductor and are intermittently connected, in the required fashion, with a direct current source. There is, however, the problem that each time when one phase in the respective coil is switched off, a negative tension peak is created as a result of self-induction, which may be, relative to the normal direction of current, discharged via diodes poled in inverse direction, which are positioned parallel to the respective switch element. This results, however, in a corresponding current in opposite direction, which must be taken into consideration in the selection and which, moreover, has a negative effect upon the efficiency of the motor.

For solving said problem, it is known, for example from WO-A 96/22629, to magnetically couple two coils each of a four-phase direct current motor. For said purpose, two coils each are applied on each pole and/or each group of poles, which are charged with direct current in the opposite direction in order to generate the desired opposite polarity of the magnetic fields generated by

same. The coil orientation of the two coils can be the same. It suffices that the ends of one of the two coils are inversely connected with the source of the direct current.

As a result of the thus produced magnetic coupling of the two coils, the tension induced in the respective coil from self-induction during discharge of the respective phase is compensated for by a tension induced in the coupled coil. The stored magnetic energy is discharged via the diode which is arranged in parallel to the switch selecting the coupled coil. This produces an improvement in the degree of efficiency.

It is also known from WO-A-96/22629 that an improvement results of the magnetic coupling of the coils of the opposite phase of such four-phase direct current motor if the coils are wound simultaneously. This results in closer proximity of the wires of the two coupled coils and thus greater coupling inductivity.

Since, however, due to the high currents, several parallel conducted wires are needed for each coil, it was necessary, following the winding process during which all parallel wires of both coils are wound at the same time, to allocate the wire ends to the two coils. To that end it was necessary to at least mark the ends of the wires or to subsequently undertake allocation of the wire ends by means of passage measurements. Altogether, automation of the winding process and allocation of the wire ends to the coils and/or the contacting of the coils was not possible.

Based on said state of the art, it is the object of the invention to create a method for winding a stator for a brushless direct-current motor and an appropriate stator, whereby, as result of simplification of the manufacturing method, automation of the winding process is possible and allocation of wire ends to the coils.

The invention solves this object with the characteristics of Patent Claims 1 and/or 5.

The invention proceeds from the recognition that as a result of dividing the winding procedure for two each coupled coils (of the opposite phases) into partial winding steps, significant simplification is attained in the manufacturing method and thus easy automation capability.

In each partial winding procedure, $2n$ preferably however only two wires are wound, whereby one half of the wires or one of the two wires of the one coil and the other half of the wires or the other of the two coils are allocated to the other coil.

In comparison with the stators produced according to the known method, there is the added benefit that the stators produced according to the method of the invention have, as a rule, a further improved magnetic coupling of the coils of the respectively opposite phases. This can be explained in that with simultaneous winding of all wires of the two coils and allocation of the wire ends after the winding procedure, there was, more or less, random allocation and positioning of the individual wires within one coil. By separation into partial winding steps, closer proximity of the individual wires of the coils is achieved, at least on balance, or more uniform distribution (viewed across the winding cross section). Particularly with the winding of only two wires respectively (one wire per coil) it is attainable that these two wires are placed close to each other over the entire length of the coil.

In addition, this results in an improved capacity of replicating the electrical properties of the stator.

According to a preferred specific embodiment of the method according to the invention for allocation of conductors to the two coils, prior to each partial winding procedure, the one terminal end of the two conductors or the terminal ends of n of the $2n$ conductors are allocated

to a first connection contact and the terminal ends of the other of the two conductors or the terminal ends of the other n of the $2n$ conductors are allocated to a second connection contact. After each partial winding procedure, the other end of the one of the two conductors or the other ends of n of the $2n$ conductors are allocated to a third connection contact and the other end of the other of the two conductors or the other ends of the other n of the $2n$ conductors are allocated to a fourth connection contact. The first and third connection contact thus serve for contacting the one coil and the second and fourth connection contact serve for contacting the other coil.

Allocation prior to a partial winding procedure is preferably done in that the (beginning) ends of the wires are connected with the appropriate connection contacts, for example by means of soldering, welding or clamping. As a result of said fixing, no additional holding of these ends is needed with an automatic winding device. After the partial winding procedure, the (posterior) ends of the wires can likewise be connected with the appropriate connection contacts.

In particular, with simultaneous winding of only two wires, it is possible to maintain in simple fashion the allocation of the wires during the entire winding procedure, so that no additional measures are needed for allocation, such as marking of the wires or passage measurements.

In the preferred specific embodiment of the stator according to the invention, connection contacts are preferably provided at one front side of the stator, said connection contacts having a number of fastening means which correspond to the number of the required partial winding procedures.

This guarantees that before or after each partial winding procedure it is possible to readily connect

the wire ends with the appropriate connection contacts, whereby for each wire end or for each group of n wire ends of $2n$ simultaneously wound wires there is available an individual attachment means or a clamp.

Additional specific embodiments of the invention are apparent from the sub-claims.

In the following, the invention is explained in more detail, making use of an exemplary embodiment represented in the drawing:

- Fig. 1 shows a schematic representation of a four-phase direct current motor with associated actuation circuit;
- Fig 2 shows a perspective representation of a stator according to the invention;
- Fig. 3 shows a schematic representation of segments of an unwound later view of the stator in Fig. 1, in order to provide an explanation of the winding procedure and
- Fig. 4 shows a perspective representation of the stator in Fig. 1 in mounted control circuit.

Fig. 1 depicts a schematic representation of a four-phase direct current motor with a stator 1, on which are provided stator coils W1, W2, W3 and W4. The coils W1 to W4 are wound on teeth or poles 3 of stator 1. The indicated magnetic coupling of the opposite phases I and III or the corresponding coils W1 and W3, and also phases II and IV or the corresponding coils W2 and W4 is obtained in that the coils W1 and W3 or the coils W2 and W4 are wound on the same stator teeth.

The winding or contacting of the coils W1 and W3 or W2 and W4 takes places in such manner that opposite magnetic fields are produced in the teeth or poles of areas in front of the stator poles 3, facing a not shown rotor. This is indicated in Fig. 1 by the dots at the coils W1 to W4.

Each coil is connected with one end or one connection to a direct current source 5. The respective other end or the respective other connection of each coil is connected with a controllable electronic switch S1, S2, S3, S4, which can be designed, for example, as power semi conductor (e.g. Power Field Effect Transistor). Each switch S1 to S4 is connected with its control inlet with a motor control unit 7, which connects, in known fashion, the coils W1 to W4 with the direct current source for certain periods of time by appropriate selection of switches S1 to S4.

Placed in parallel to each controllable switch S1 to S4, is a diode D1 to D4, whereby the passage direction of the diodes is selected in such manner that upon closing of the appropriate switch, the associated diode becomes blocked.

As already explained, as a result of coupling the respectively opposite Phases I and III or II and IV and diodes D3 and D1 and D4 and D2, discharge is obtained of the stored magnetic energy during the off-switching of the respective phase, which guarantees an improvement of the efficiency of the motor.

Fig. 2 depicts the constructive design of an appropriate stator 1 in perspective view. The indicated stator has twelve stator poles 3. The stator body 9 comprises in customary fashion packaged stator metal sheets, which extend vertically vis-a-vis the longitudinal axis of the stator.

The packet of the stator metal sheets can be initially produced in the usual fashion by stamping the packet together with two or more each of the metal sheets being joined by means of exertion of spot-pressure.

Subsequently, the package of stator metal sheets is spray-coated with a plastic body, with plastic coating being also generated in the interior of the stator teeth. Consequently, it is no longer necessary, as in the past, to provide a powder coating for these regions of the stator teeth in order to avoid damage to the insulation layer of the coil wires, specifically during the winding procedure.

At the same time, winding aids 11 are molded to the front sides of the stator teeth 3, which act as a guide for the wires during the winding of the coils W1 to W4, and which, concurrently, fix in their position those parts of the coils which protrude beyond the front sides of the stator teeth 3.

At one upper side, the stator body 9 has a molded-on ring 13 with a shoulder 13a. Into said frontal shoulder 13a, connection contacts 15 are pressed in. To that end, ring 13 is molded with appropriate recesses for the connection contacts, into which then connection contacts 15, made of sheet metal by means of stamping or bending, are pressed in with their terminal lugs.

The upwardly extending wall 17 of ring 13, above the shoulder 13a of ring 13 serves for fixing and fastening a control circuit 17, as is evident from Fig. 4. The control circuit can have a plastic-coated stamped grid 19 with an appropriate recess 21, which engages with wall 17 of ring 13. The underside of the stamped grid 19 can rest on the shoulder 13a of ring 13.

The connection contacts 15 engage with the contacting perforations 23 in the conductor tracks 19a of the stamped grid 19 and can be joined with same by means of soldering or similar method.

As a result of spray-coating with plastic the packet of the stator metal sheets in one single work step, whereby the interior regions of the stator teeth 3 are spray-coated and, at the same time, ring 13 and the winding aids 11 are spray-molded on, one obtains extremely cost-effective manufacturing of stator 1.

In the following, the method for winding stator 1 is explained in more detail, making use of Fig. 3.

It should first be noted that in the represented exemplary embodiment each one of coils W1 to W4 extends over a totality of six stator teeth 3, which are divided, in known fashion, into two each other radially facing groups of three each adjacent stator teeth. As already explained, these six stator teeth respectively support two coupled coils, i.e. coils W1 and W3 or W2 and W4. Two of these groups are depicted in Fig. 3, whereby, hereinafter, these coils are identified for the sake of simplicity as W1 and W3. The remaining six stator teeth 3 for coils W2 and W4 are wound in similar fashion. In this regard, the method described below is to be employed in the appropriate manner.

Each of the coils W1 and W3 comprises, due to the required high current intensities, several, in parallel arranged partial coils of individual wires. According to the invention, in each instance, 2 or $2n$ wires (i.e. an even number of wires) - in the represented exemplary embodiment the two wires 25, 27 - are simultaneously wound on the appropriate stator teeth 3.

To that end, the beginning ends of the 2 wires 25, 27 are first respectively connected with a first 15_I and a second 15_{II} of the connection contacts 15. For that purpose, the connection contacts present V-shaped clamping grooves 15a, into which the (insulated) wire ends are embedded and are fixed and contacted by pressing together the walls of the clamping grooves 15a.

After fixing of the wire ends, the first stator tooth 3 of the first group of three is wound. This is done in counter-clockwise direction with respect to the exemplary embodiment represented in Figure 3. Following application of the desired number of windings, one then proceeds to the neighboring stator tooth, and the latter is wound in opposite direction with the desired number of windings (the middle stator tooth 3 of the left group in Fig. 3). Finally, one proceeds to the last stator tooth of the first group of three and it is provided with the desired number of windings. This again is done in the winding direction of the first stator tooth.

After that, one proceeds to the first stator tooth of the diametrically opposed group of three (in Fig. 3, the right stator tooth of the right group of three) and said stator tooth is wound. The winding of this second group of three of the stator teeth is done in similar fashion.

After the winding of the last stator tooth of the second group of three (the left stator tooth of the right group of three in Fig. 3), the end of wire 25 is connected with the third connection contact 15_{III} and the end of wire 27 with the fourth connection contact 15_{IV} . The allocation of the wire ends to the connection contacts 15 is initially insignificant with respect to said first partial winding step. What must, of course, be observed is which of the connection contacts 15 corresponds to said coils W1 and W3. In other words, for future selection of coils it must be known which of the

two coils corresponds to what two connection contacts. The coils W1 and W3 are equivalent to each other, since they present the same winding direction.

Following completion of said first partial winding step, a second partial winding step is undertaken in like fashion. The only difference being that the wire ends are connected with additional attachment means of clamping grooves 15a of the first to fourth connection contacts.

This makes possible simple attachment of the wire ends without the need of loosening the previously wound wires.

In these and perhaps additional partial winding steps, attention must be paid, however, that with respect to the first partial winding step, the selected allocation of the connection contacts 15_I and 15_{III} to the one coil is observed, for example the first coil W1, and/or the connection contacts 15_{II} and 15_{IV} to the other coil, for example, coil W3.

Usually, however, one must establish from the very beginning that certain connection contacts correspond to certain specified coils or coil ends.

By already allocating the wire ends to certain connection contacts prior to the actual winding and observance of said allocation during the partial winding procedure, it is possible, in simple fashion, without additional measures, such as marking of the wires or implementation of passage measurements, to correctly connect, following the partial wind procedure, the wire ends with the proper connection contacts. It applies specifically to a small number of simultaneously wound wires (preferably two wires).

Overall, as many partial winding procedures are carried out as are necessary in order to reach the required number of parallel wires per coil W1, W3. The number of attachment means or clamping grooves 15a preferably corresponds to the number of the required partial winding steps.

The two other coupled coils W2 and W4 are manufactured in similar fashion, whereby attention needs to be paid that the orientation of the winding must also be correctly selected with respect to the already provided coils W1 and W3.

The represented method is, of course, not only applicable with respect to four-phase direct current motors, but also for motors with any (even) number of phases, whereby, in each case, the coils of two phases are magnetically coupled.

Patent Claims

1. Method for winding a stator for a brushless direct current motor,
 - a) which has a stator body (9) with a pre-determined number of to be wound stator teeth (3),
 - b) wherein the stator teeth (3) are respectively wound with two coils (W1, W3; W2, W4), which are magnetically coupled and which permit the generation of opposite magnetic fields by the supply of current with variable directional orientation, and
 - c) wherein each of the two coils (W1, W3; W2, W4) comprises a predetermined number of conductors placed in parallel,

characterized in that

 - d) the stator teeth (3) are each simultaneously wound, in several partial winding steps, with two conductors (25, 27) or an even number of $2n$ conductors,
 - e) that one of the two conductors (25, 27) or n conductor of the $2n$ conductors of the one coil and the other of the two conductors (25, 27) or the other n conductor of the $2n$ conductors are allocated to the other coil

and

 - f) that a predetermined number of partial winding procedures is performed until the predetermined number of conductors per coil (W1, W3; W2, W4) has been reached.

2. Method according to Claim 1, **characterized in that** for allocation of the conductors (25, 27) to the two coils (W1, W3) prior to each partial winding procedure, the one end of the one (25) of the two conductors (25, 27) or the one end of n of the 2n conductors are allocated to a first connection contact (15_I) and the one end of the other (27) of the two conductors (25, 27) or the one end of the other n of the 2n conductors are allocated to a second connection contact (15_{II}) and that after each partial winding procedure the other end of the one (25) of the two conductors (25, 27) or the other end of the n of the 2n conductors are allocated to a third connection contact (15_{III}) and the other end of the other (27) of the two conductors (25, 27) or the other ends of the other n of the 2n conductors are allocated to a fourth connection contact (15_{IV}).
3. Method according to Claim 2, **characterized in that** the one end of the one (25) of the 2 conductors (25, 27) or the one end of n of the 2n conductors are connected, prior to the partial winding procedure, with the first connection contact (15_I) and the one end of the other (27) of the two conductors (25, 27) or the one ends of the other n of the 2n conductors with the second connection contact (15_{II}).
4. Method according to one of Claims 1 to 3, **characterized in that** the simultaneously wound conductors (25, 27) are conducted in close proximity during the winding procedure and preferably in a position maintained beyond the winding procedure.
5. Stator for a brushless direct current motor,
 - a) which presents a stator body (9) with a pre-determined number of wound stator teeth (3),

- b) wherein the stator teeth (3) are respectively wound with two coils (W1, W3; W2, W4) which are magnetically coupled and which facilitate by the supply of current of variable directional orientation the generation of opposite magnetic fields, and
- c) wherein each of the two coils (W1, W3 or W2, W4) comprises a predetermined number of in parallel arranged conductors,

characterized in that

- d) two each conductors (25, 27) of which one conductor is allocated to the one coil and the other conductor to the other coil, or $2n$ conductors, of which n conductor is allocated to the one coil and the other n conductors to the other coil, are conducted in a substantially constant position vis-a-vis each other over the entire coil length .

6. Stator according to Claim 5, **characterized in that** two each or $2n$ conductors are conducted in close proximity.
7. Stator according to Claim 5 or 6, **characterized in that** the stator body (9) presents, preferable at one frontal side, connection contacts (15), which respectively are connected with the ends of the respective two, the magnetically-coupled coils (W1, W3; W2, W4) forming conductors.

8. Stator according to Claim 7, **characterized in that** the connection contacts (15) simultaneously serve for electrical contacting and mechanical fastening of a control circuit (17) preferably having a stamped grid (19) or a printed conductor plate.
9. Stator according to one of Claims 5 to 8, **characterized in that** the first and the second (15_I, 15_{II}), preferably also the third and fourth connection contacts (15_{III}, 15_{IV}) have means of attachment (15a) which facilitate successive connection, specifically clamping of conductor ends without the need of loosening already connected conductor ends.
10. Stator according to one of Claims 5 to 8, **characterized in that** the connection contacts (15) have a number of attachment means (15a) which correspond in number to the required partial winding steps according to the method to one of Claims 1 to 4.

Fig. 1

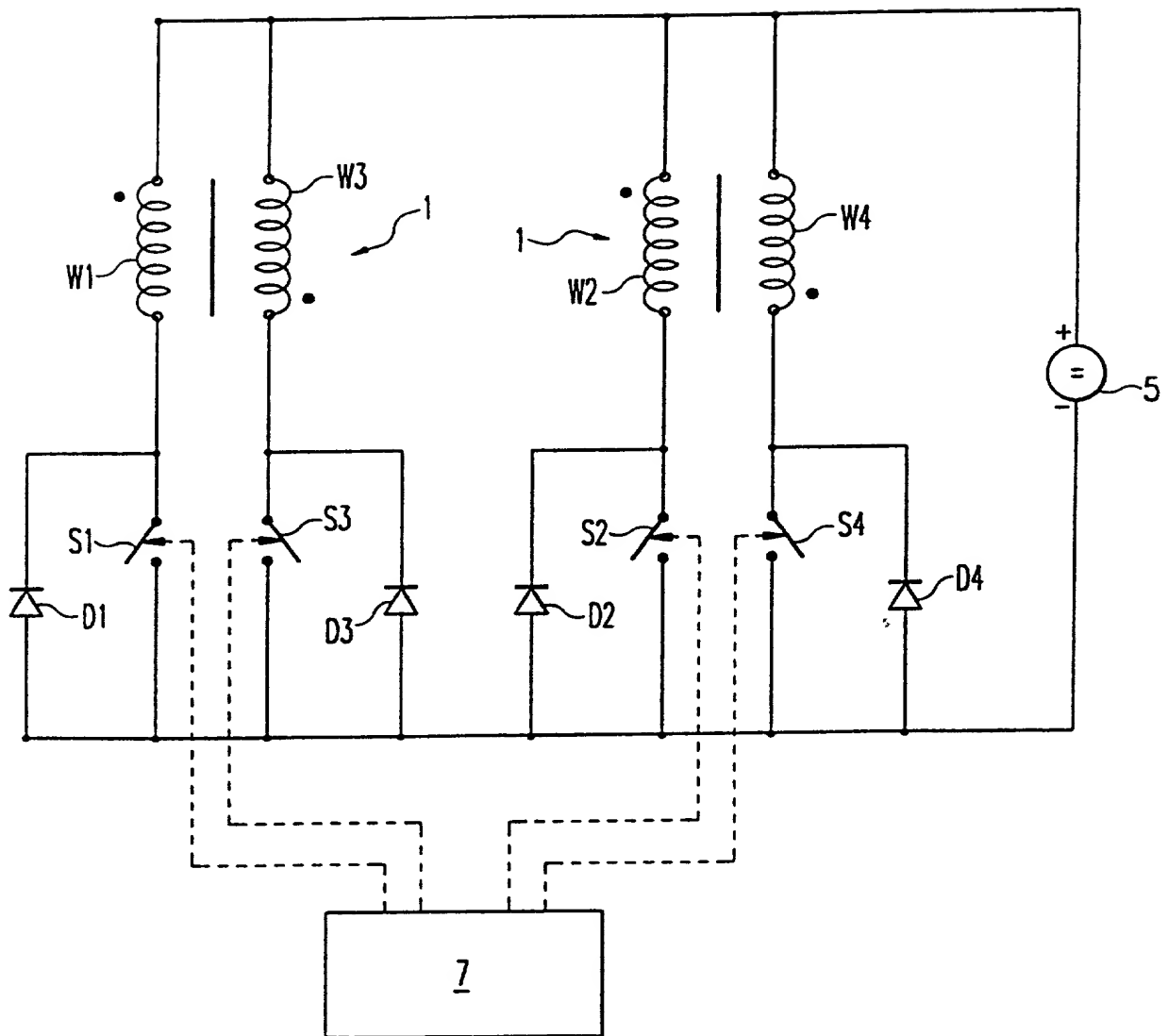


Fig. 2

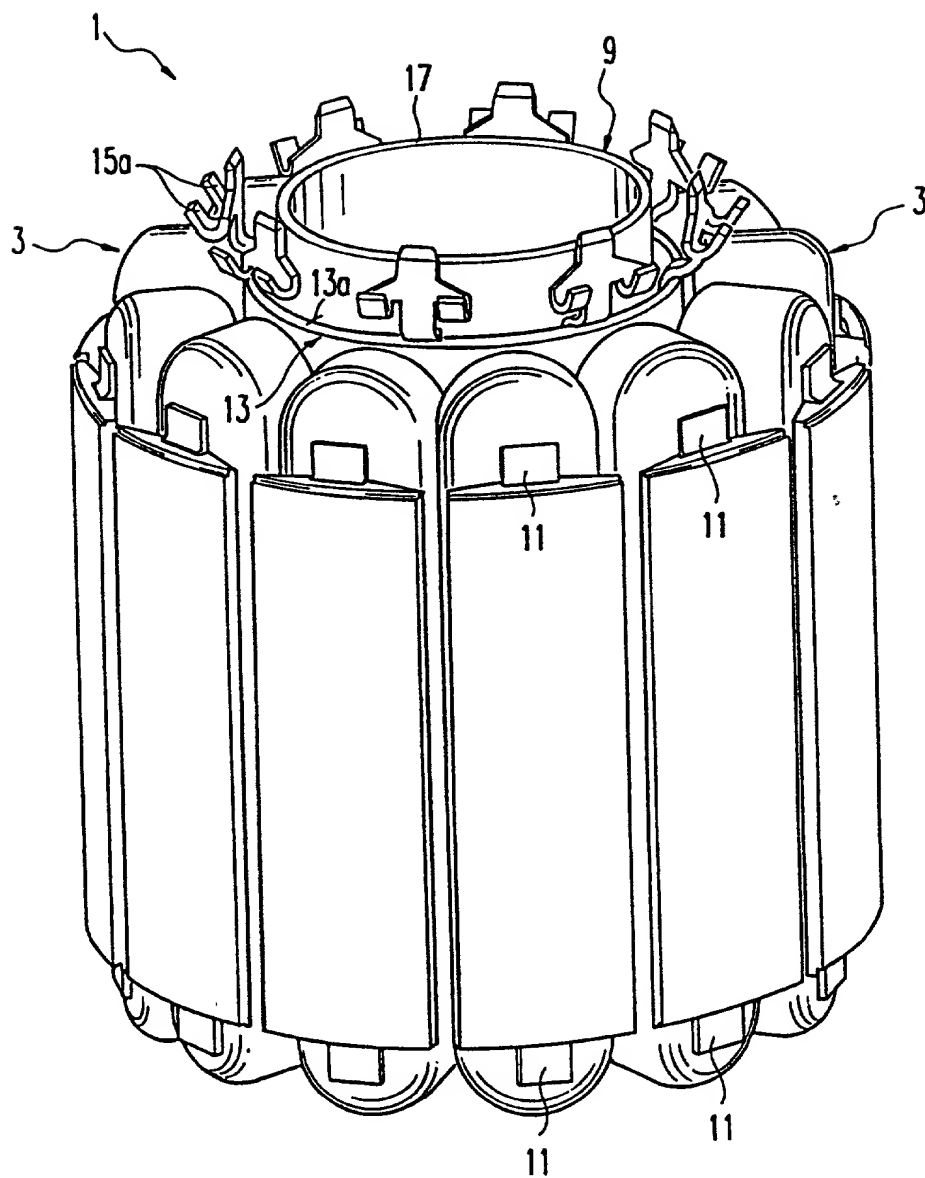


Fig. 3

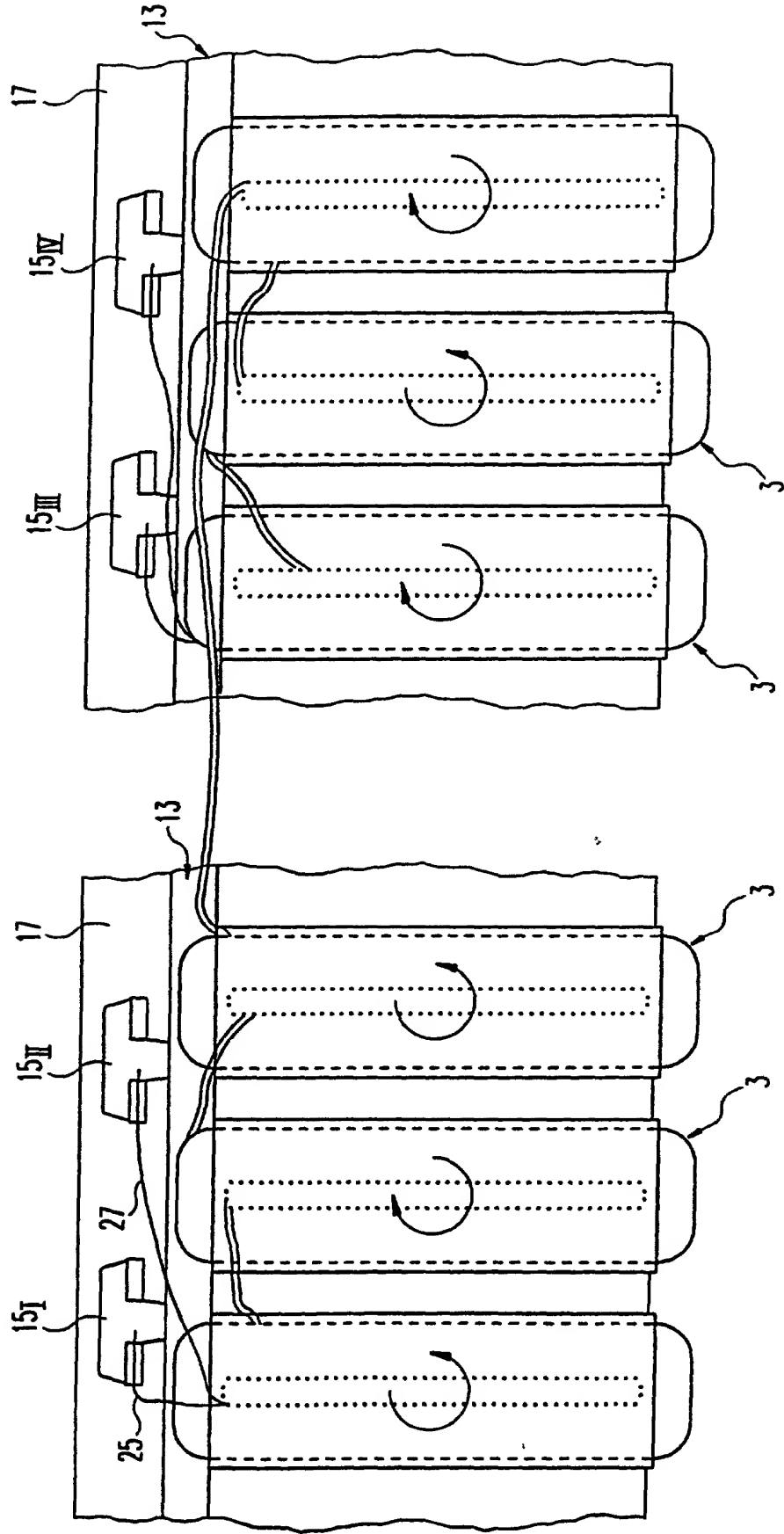
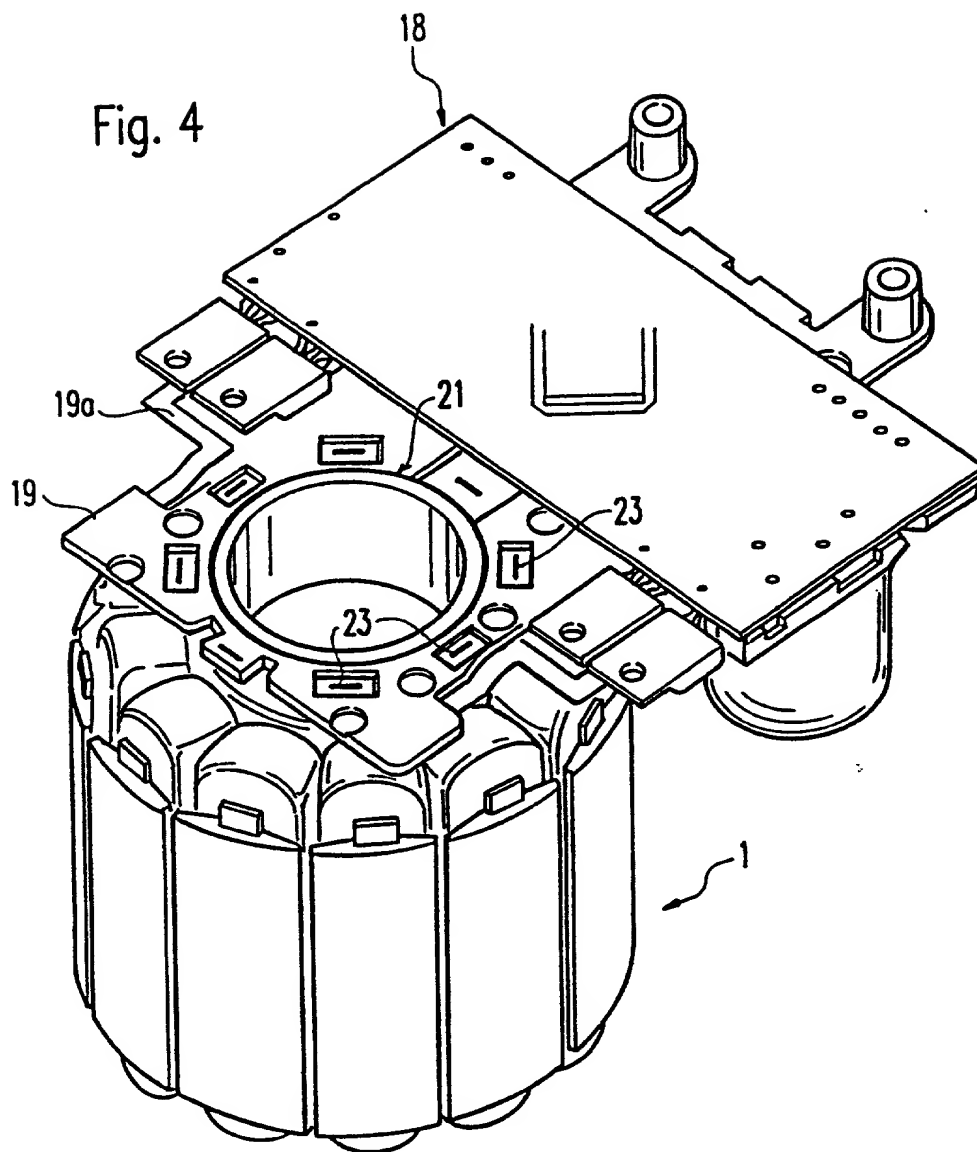


Fig. 4



18.6.00

Attorney Docket No.: TRW 2 256

DECLARATION FOR PATENT APPLICATION

As the below named inventors, we hereby declare that:

Our residence, post office address, and citizenship are as stated below next to our names.

We believe we are an original, first, and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**STATOR AND STATOR WINDING METHOD FOR USE WITH BRUSHLESS
DIRECT CURRENT MOTORS**

the specification of which was filed on March 17, 2000 together with a Substitute Specification and a Preliminary Amendment on March 17, 2000, and accorded Serial No. 09/508934.

We hereby state that we have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37 Code of Federal Regulations § 1.56(a).

We hereby claim foreign priority benefits under Title 35, United States Code § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Germany 197 40 937.7 Filed September 17, 1997

We hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

Not applicable.

-2-

We hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

PCT Application No. PCT/DE98/02765, Filed September 17, 1998

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We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

-3-

100

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